Modelling of localised necking in thermo-mechanical sheet metal forming

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In sheet metal forming, assessing the formability of a part requires the prediction of localised necking. A pragmatic approach is to compare calculated principal strains with experimentally determined forming limit curves (FLCs). However, the FLCs are known to depend on the strain path and temperature history and most experimental FLCs are determined for straight deformation paths at room temperature. For thermo-mechanical sheet forming, in which a temperature gradient is applied during sheet forming, FLCs are virtually useless.

For commonly applied ductile materials, local necking in sheet material can well be described—at least initially—as a geometrical instability. This type of localisation can be determined numerically with a Marciniak–Kuczynski (M–K) analysis. Two important material parameters that influence the calculated forming limits through necking are the work hardening and the shape of the yield locus. For thermo-mechanical processes, the temperature and strain rate dependent material behaviour must be described accurately by the material model. A proper description of the curvature of the yield locus between the plane strain and equi-biaxial stress points is extremely important. The use of the von Mises criterion leads to a gross over-estimation of the forming limit in biaxial tension.

It is recognised that a FEM analysis with shell elements resembles the M–K analysis very much. For uniform deformations a band with slightly reduced thickness is necessary to trigger localisation. This is the main disadvantage of the M–K analysis. In practical forming conditions, however, the non-uniformity of the process automatically triggers localisation and an arbitrary initial imperfection is not needed. FEM models have the additional benefit that boundary conditions, non-proportional deformation and *e.g.* friction with the tools are completely included.

Key words: yield locus, localisation, necking, finite elements, thermo-mechanical analysis